UNCLASSIFIED

JADS JT&E

The Development of a Real Time Stochastic Radar Simulation (VSTARS)

By: Gary Marchand and MAJ Terry Schmidt

December 1996

Joint Advanced Distributed Simulation
Joint Test Force
2050A 2nd St. SE
Kirtland Air Force Base, New Mexico 87117-5522

UNCLASSIFIED

Go Back

The Development of a Real Time Stochastic Radar Simulation (VSTARS)

Gary Marchand, SAIC
marchand@jads.kirtland.af.mil
(505) 845-1165
MAJ Terry Schmidt, USA
schmidt@jads.kirtland.af.mil
(505) 846-1015
JADS JTF
11104 Menaul NE
Albuquerque, NM 87111

Abstract

The End-To-End Test (ETE) is a test being conducted under the auspices of the Joint Advanced Distributed Simulation (JADS) Joint Test and Evaluation (JT&E). The purpose of the ETE is to investigate the utility of using advanced distributed simulation (ADS) to augment both developmental and operational testing of the Joint STARS. The basic concept behind the ETE is to augment the Joint STARS environment with a virtual environment created by thousands of simulated entities, or targets. This virtual environment is imaged by simulations of the radar systems contained within the Joint STARS E-8C aircraft and mixed with real radar returns to provide a robust operational environment for testing of the system.

The total simulation environment representing the Radar Subsystem aboard the E-8C aircraft is called a Virtual Surveillance Target Attack Radar Sensor (VSTARS). It is composed of a DIS NIU; a radar processor simulation and integrator (RPSI), and containing two real time stochastic radar simulations with necessary data bases and libraries. VSTARS will be verified and validated for use in both testing (DT&E and OT&E) and training and accredited for use in the JADS ETE.

This paper describes the design considerations involved in developing VSTARS, the process involved, and the status of the project.

Background

The Joint Advanced Distributed Simulation (JADS) Joint Test and Evaluation (JT&E) has been chartered by the Office of the Under Secretary of Defense (Acquistion and Technology), Office of the Director, Test and Evaluation "...to investigate the utility of Advanced Distributed Simulation (ADS) for both developmental test and evaluation (DT&E) and operational test and evaluation (OT&E). JADS will investigate the present utility of ADS, including Distributed Interactive Simulation, for T&E; and finally, identify the requirements that must be introduced in ADS systems if they are to support a more complete T&E capability in the future."

The approach taken by JADS is to select discrete, well defined, slices of the broad T&E spectrum, conduct ADS augmented test activities upon specific systems that are representative of these slices, and address the issues identified within our charter. In addition, ADS activity external to JADS will be evaluated to provide as broad a base for our conclusions as is possible.

The emphasis of the JADS JT&E is on the performance of the ADS components and their contribution to testing, rather than any particular system under test or class of weapon system. Areas of interest include network capabilities and performance, relationships between data latencies, and ADS induced data anomalies.

The End-To-End Test (ETE) is one of the three tests within the JADS JT&E program. The ETE is designed to evaluate the utility of ADS to support the testing of a C4I system, the Joint Surveillance Target Attack Radar System (Joint STARS), while the system performs the end-to-end loop of detect, track, target, cue a weapons system, and assess battle damage. Joint STARS is composed of both an airborne and ground segment along with the necessary communications subsystems. The E-8 airborne system and the Ground Station Modules (GSM) together provide the surveillance, target detection, and tracking required to assist commanders in understanding the enemy situation and taking action to destroy enemy forces.

A previous shortfall in the testing of C4I systems, especially those using large area sensor systems such as Joint STARS, was the inadequate numbers of forces, either friendly or adversary, available to realistically portray the expected operational environment. In addition, systems were often tested in isolation without the complementary suite of other C4I and weapon systems with which to interact. The ETE is designed to add an augmented operational environment and a complementary suite of C4I and weapons systems with which Joint STARS would interact to determine if ADS can alleviate these testing shortfalls.

In addition, the ETE utilizes the technology specified by the IEEE 1278 Standard, known as Distributed Interactive Simulation (DIS). This standard specifies a distributed communication architecture, defines protocol data units (PDU) that carry information between the nodes of the distributed simulation, provides common enumeration values for use within the PDUs, and most importantly, provides a common interface into the distributed simulation that allows its reuse.

Requirement for a VSTARS

Federal Statues require that the actual system, or system components, be used in all testing. This dictates that if one wants to add to the operational environment experienced by Joint STARS through the use of ADS, then one must enter the Joint STARS through its sensor, the Joint STARS Radar Subsystem. Once the information has entered the system through its sensor, it may then be distributed and used for surveillance, target detection, and tracking by the remaining Joint STARS subsystems. To be useful for testing, however, the ADS, or virtual, information must pass a rigorous VV&A, must be indistinguishable from the real radar returns, and the functioning of the system must remain the same.

During the feasibility study phase of JADS, it quickly became apparent that no simulation or simulations existed that could provide the required fidelity, operate in real time throughout the ground radar coverage area, and emulate the two radar modes, moving target indicator (MTI) and synthetic aperture radar (SAR). In addition, most MTI simulations represented at best a single operator's work station, used estimated timelines, and performed as if they had a dedicated radar subsystem. A viable SAR simulation did not exist. Common practice was to substitute pre-loaded images that often had little or no operational relevance.

This dictated the need, therefore, for a Virtual Surveillance Target Attack Radar Sensor (VSTARS) which will function alongside the real radar subsystem, onboard the aircraft, and interact with the Operations and Control Subsystem in a seamless manner. This also requires that the architecture for VSTARS be very similar to the architecture of the real system it is emulating.

The VSTARS Architecture

The VSTARS architecture is based upon the architecture of the Radar Subsystem onboard the E-8C aircraft and is designed to function in three primary modes: (1) all real, where only the aircraft's radar subsystem is providing information on the real environment; (2) mixed mode, where both the radar subsystem and VSTARS are providing information on the real and virtual environments; and (3) virtual mode, where only VSTARS is providing information on a virtual environment.

Another major consideration in developing the architecture for VSTARS was the desire to develop a system that would be able to operate on COTS equipment without requiring the presence of the E-8C platform. This was crucial to the early development of VSTARS, makes DT&E possible, provides a cost effective alternative to testers of other systems that require Joint STARS participation, and results in a simulation directly usable by the trainer.

In addition, VSTARS architecture is modular and will allow its easy adaptation to represent improved versions of Joint STARS or other sensor systems that are currently under development. It is fully integrated into the radar subsystem architecture of the E-8C and will be transparent to the user, whether in the air or on the ground. A top level block diagram of the COTS version of the architecture is shown in Figure 1. Figure 2 shows the E-8C version of the architecture integrated into the subsystems on board the aircraft.

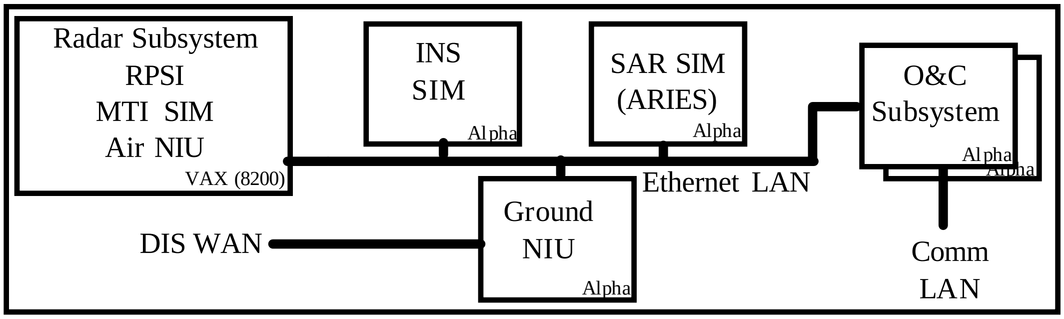

Figure 1: COTS VSTARS Architecture

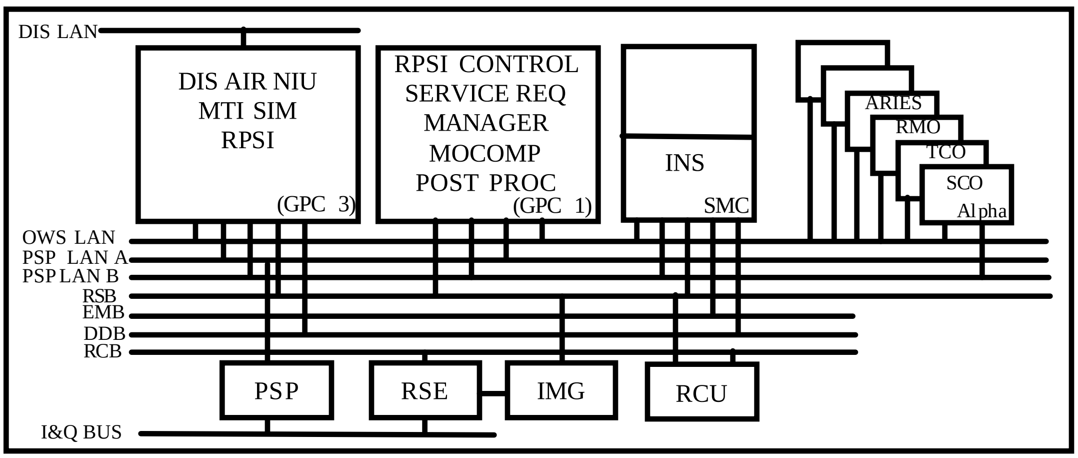

Figure 2: E-8C VSTARS Architecture

The primary difference between the two architectures is the need to simulate the Integrated Navigation Subsystem (INS) and the Operator Work Station (OWS) LAN, with Alpha 820 computers in the COTS VSTARS architecture. These simulations provide the capability for the COTS VSTARS to function without an actual E-8C present. Since these function the same as the actual subsystems, they will not be discussed further in this paper.

In both architectures, the DIS network interface unit (NIU) functions are divided between two components. The GNIU represents the portion of the NIU that is connected to the DIS network, and it receives entity state PDUs (ESPDU) from the network. It also transmits an ESPDU representing the location and existence of the E-8C. In addition, it performs coordinate conversion, from Earth-Centered-Earth-Fixed to Topocentric Coordinate System, and reduces the ESPDU in size from its standard of 1152 bits down to 192 bits. The reduced data packet is then sent to the ANIU where dead reckoning is performed. Entity state updates are provided to a target data base either through the receipt of an entity data packet or through dead reckoning updates. The details of this process are contained in an accompanying paper, Modification of the Entity State PDU for Use In the End-To-End Test. This split NIU is required due to the real separation of the aircraft from the DIS network and the need to minimize bandwidth requirements, which dictates that the ESPDU be reduced in size and dead reckoning be performed on board the aircraft.

The heart of the VSTARS is the Radar Processor Simulator and Integrator (RPSI) and the two radar simulations, a moving target indicator radar simulation (MTI SIM) and a synthetic aperture radar simulation called the Advanced Radar Imaging Emulation System (ARIES). These three components of VSTARS will be described in more detail in the remainder of this paper.

The Radar Processor Simulation and Integrator (RPSI)

The RPSI is the realization of a concept for mixing real and virtual radar returns that was developed jointly by JADS and Northrop Grumman, the developer of the E-8C. From the statement of work, the RPSI "...will be capable of mixing virtual MTI returns, virtual terrain, and virtual SAR images, in a seamless manner, with actual radar returns (MTI and SAR)." It will do this without causing any degradation to the aircraft system's capabilities for handling actual (live) targets. Additionally, it must do this in a manner that is transparent to the users of the products, or in other words, validated smoke and mirrors without the smoke and mirrors being detected.

This requires that the RPSI functions within the actual radar processor on board the aircraft. It must be triggered by the same message structures currently used to communicate with, and within, the radar subsystem; must nominally work within the radar subsystem timelines; and must output its reports in the same formats currently used by the radar subsystem.

As can be seen from Figure 2, the RPSI Control Program resides on the same computer as the Radar Data Processor (RDP). The remainder of the RPSI, except for ARIES, resides in one of the spare general purpose computers and communicates over the PSP LANs and the OWS LAN. ARIES resides in its own computer and communicates over the PSP LAN and the OWS LAN. It should be noted that though shown as separate computers, the eventual implementation may reside on a multi-processor chassis functioning as independent computers. The functional software flow diagram for the RPSI Control Program is shown in Figure 3.

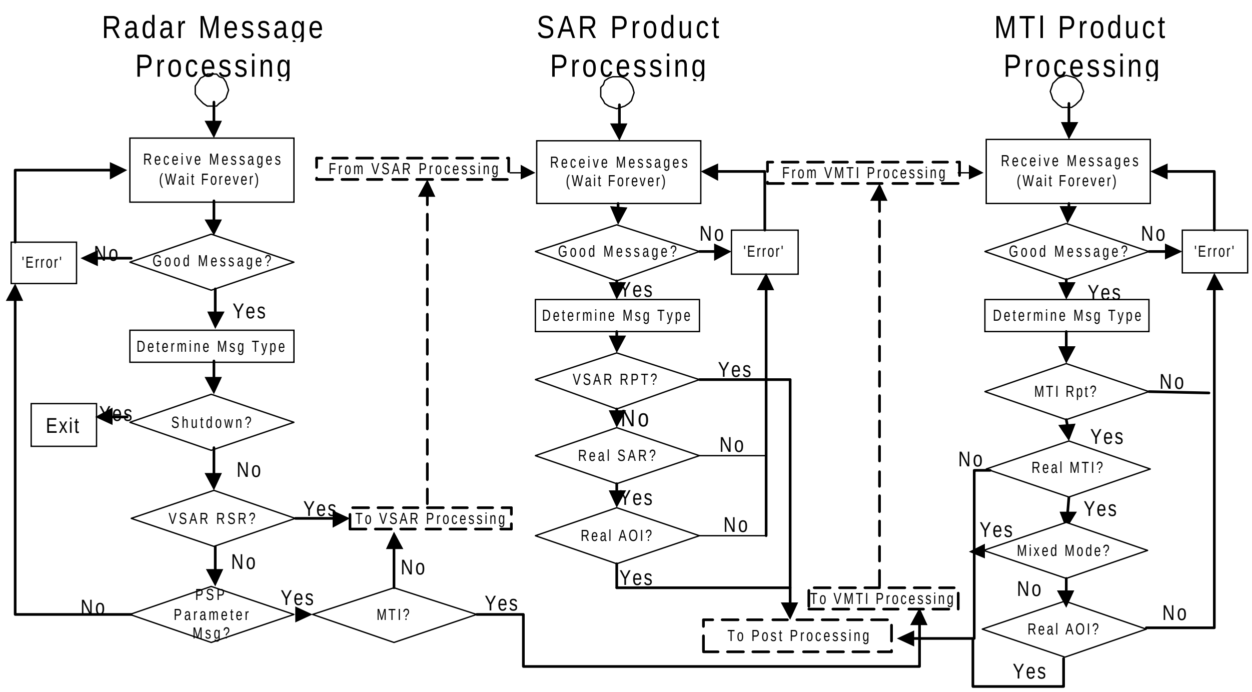

Figure 3: RPSI Functional Software Flow Diagram

The simulation portion of the RPSI will be discussed later in this paper. When a Radar Service Request (RSR) is received over the OWS LAN, a check is made to see if it is a request for a virtual SAR product The SAR RSR acts as a get ready message for ARIES and allows it to perform some preparatory steps prior to receiving PSP parameter messages.

The PSP parameter messages from the radar processors are the key messages received by the RPSI. These messages contain navigational, pointing, and target information taken from the E-8C radar. They are further processed by the RPSI and allow the RPSI to decide whether it should allow real radar products, or virtual radar products, to proceed to the post processor. Several things should be noted at this point. First, all radar missions are performed by the radar on board the aircraft. Initialization parameters determine if the delivered MTI radar products will be all real, mixed, or all virtual. Second, when operating in the mixed MTI mode, one can have geographical areas that are only real MTI returns, only virtual MTI returns, or a mix of virtual and real MTI radar returns. The mixed MTI mode allows one to keep real weather effects, false targets, and clutter along with civilian background traffic. Finally, SAR images consist of only virtual images or real images. There is no mixed SAR mode and thus one must be careful when using mixed MTI mode and SAR, or the smoke and mirrors will become visible to the observant operator.

The MTI Simulation

The MTI Simulation that will be used in VSTARS has been developed by Northrop Grumman and is based upon an engineering model used by Northrop Grumman during the development of the E-8C radar. As such, it has gone through many cycles of model-test-model and is considered to be a valid model of the MTI mode of the E-8C radar. It characterizes target probability of detection (Pd) and location accuracy, in the presence of clutter assuming a constant false alarm rate, as a function of key radar system variables that can be implemented in the real-time target detection stream of the MTI radar system.

The simulation receives PSP messages that indicate the limits of the current radar beam footprint (dwell quadrilateral) and determines what portion of the footprint is allowed virtual targets. It then determines which moving virtual targets are located within the virtual portion of the dwell quadrilateral, based upon their latest dead reckoned position. Once the possible target set is determined, Pd is applied and the detected target set is derived. Location error is then applied to the detected targets and the target set is sent to the radar post processor. A false alarm simulation runs whenever the MTI SIM is operating in the 'virtual only' mode. This generates false returns, including meteorological effects, based upon radar system variables. The software flow diagram for the MTI simulation is shown in Figure 4.

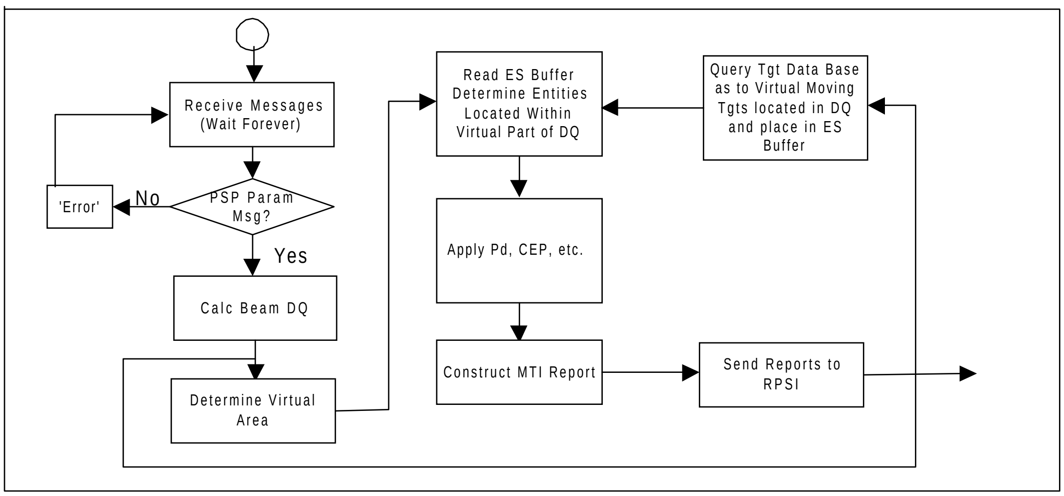

Figure 4: MTI Software Flow Diagram

All of this must occur within the time line of the actual radar mission, or close enough to it that the requester will not observe any difference. The MTI timeline is shown in Figure 5. Preliminary timing studies using 20,000 moving targets and prototype software have indicated that the final report will be delayed about 9 msec.

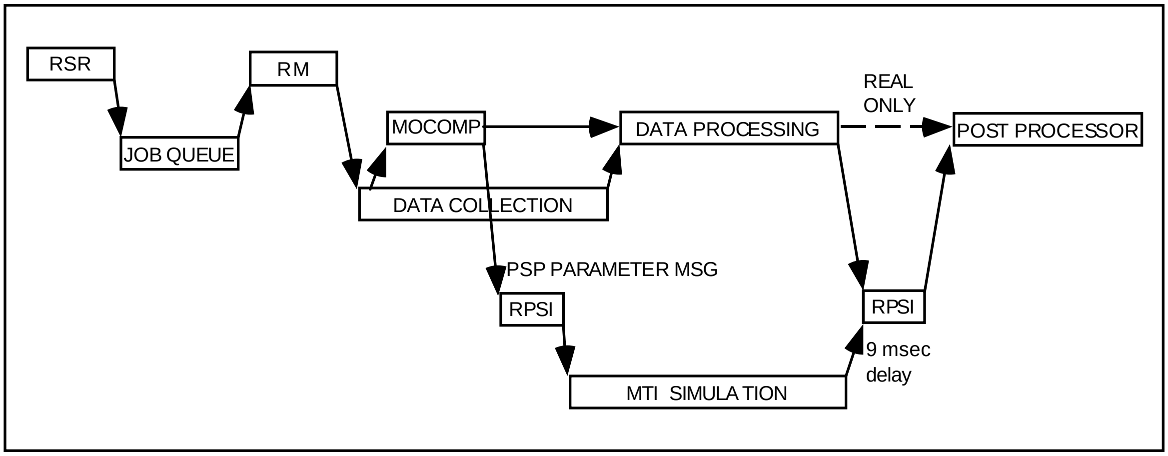

Figure 5: MTI Time Line

SAR Simulation (ARIES)

The VSTARS SAR simulation, named the Advanced Radar Image Emulation System, is based upon XPATCHES, a comprehensive SAR system simulation developed and validated by Loral Defense System-Arizona for Wright Laboratory. XPATCHES has been successfully applied to a number of automatic target recognition, sensor design and system analysis programs for Wright Laboratory.

ARIES, currently under development by Lockheed Martin Tactical Defense Systems-Arizona, extends the capabilities of XPATCH target signature modeling, XPATCHES image scene generation, and interfaces with Northrop Grumman's RPSI to provide a complete methodology for the real- time simulation of the Joint STARS SAR mode of operation.

ARIES will be initiated by the receipt of a RSR requesting a SAR image with an image center point specified within the virtual portion of the ground radar coverage area (GRCA). The GRCA covers thousands of square kilometers in size, is specified in the mission orders, and is the area scanned continuously by MTI wide area surveillance. It also acts as a limiting area for special radar products such as a SAR image. The virtual portion of the GRCA will be so indicated upon initialization of the RPSI. ARIES, upon initialization of the RPSI, will create four data bases within hardware RAM containing elevation and feature data for the GRCA, a contour map of the terrain within the GRCA, and a feature target function library for all the features contained in the feature data base.

Once the center point of the virtual SAR image is known, ARIES will over sample around the center point and extract the elevation data for an area that will exceed the image area coverage. ARIES determines from the contour map if any terrain feature outside the image area will influence the image area. ARIES will also determine which terrain features exist within the target area. Using this data, ARIES will develop a ground truth point map of the sampled area.

ARIES will wait for the PSP parameter message to arrive before doing any further processing. The PSP parameter message, a product of the actual scanning of the area of interest (AOI) by the radar, contains such information as actual grazing and squint angles, size of imaged area, and other information needed by ARIES to image the AOI. Once the PSP parameter message is received, ARIES will select the actual image area from the ground truth point map and begin applying XPATCHES image generation algorithms to generate the SAR scene. The ARIES system design is shown in Figure 6.

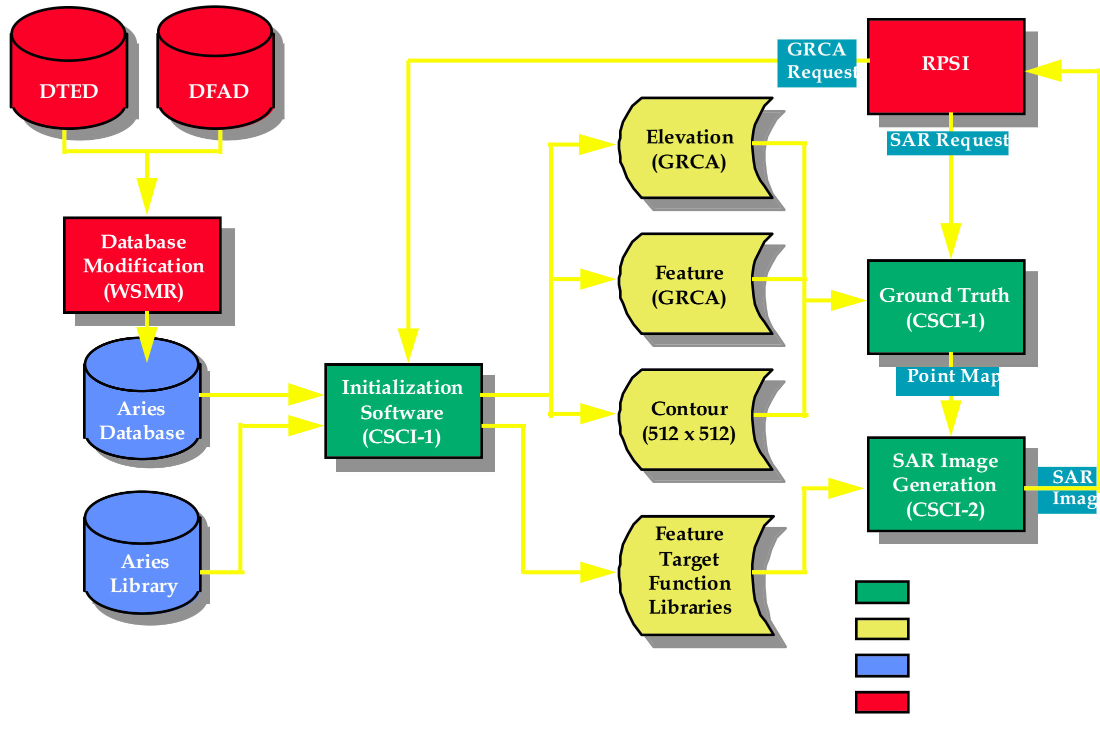

Figure 6: ARIES System Design

The RPSI will also receive the PSP parameter message and will use the actual imaged area to determine what virtual targets are located within the AOI. It will then send this target list to ARIES, which will obtain from Feature Target Function Libraries the appropriate target image chips for insertion into the SAR image. Moving targets will be displaced, or smeared, within the image as appropriate. Once this is accomplished, the image will be sent to the RPSI for forwarding to the Post Processor. The SAR Timeline is shown in Figure 7. Timing studies are still underway at both Lockheed Martin and Northrop Grumman. Early indications are that it will take ARIES approximately one or two seconds longer, at worst, to generate a SAR image than the real radar. Since the requester has no way of knowing when the SAR mission was initiated, we do not feel that this delay will be noticed.

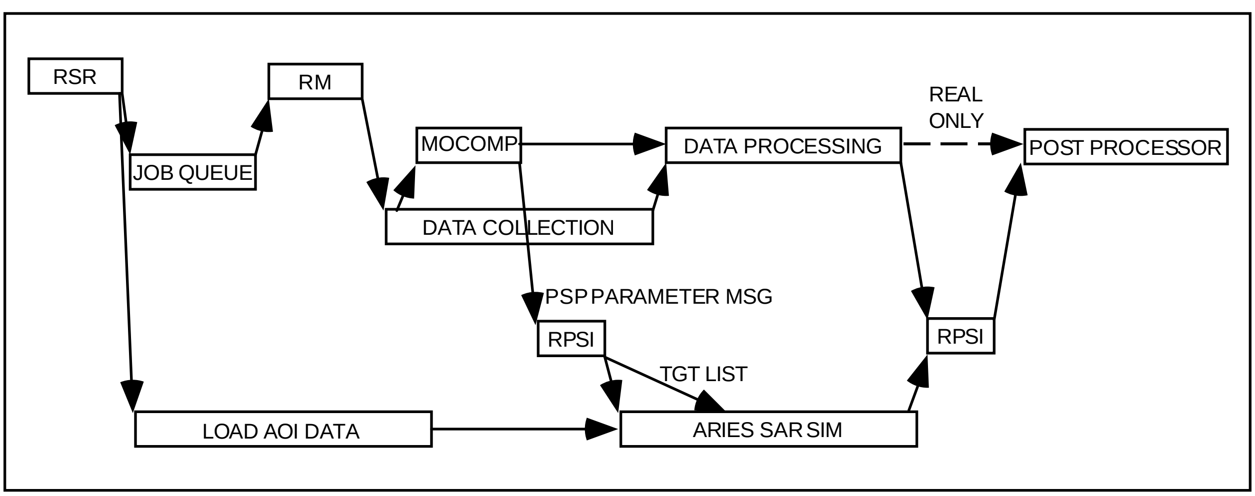

Figure 7: SAR Timeline

Go Back

Summary and Conclusions

VSTARS is a stand-alone DIS compatible model of the E-8C radar that will work in real time and intermix real and virtual target information in a seamless manner. It will enable any user requiring Joint STARS imagery to work with only real data, a mix of real and virtual data, or only virtual data. Any DIS-compatible entity level simulation will be able to provide input into VSTARS. Architectural and engineering designs have been completed, prototype software has been developed, and timing and functional studies have been performed or are underway. VSTARS is currently being developed at Northrop Grumman and Lockheed Martin for the JADS JTF and is expected to be completed by September 97.

References

(1) Richard Floto, "A Real-Time Stochastic MTI Radar Simulation for DIS Application," Presented at the American Institute of Aeronautics and Astronautics Flight Simulation Technology Conference, San Diego, CA, July 1996.

(2) Architectural Design Report for the Radar Processor Simulation for the Joint Surveillance Target Attack Radar System (Joint STARS), Document No. JADS-RPT-001, Code Ident: Q002, date March 1996, Prepared by: Northrop Grumman, 2000 W. NASA Blvd., Melbourne, Florida 32901

(3) Engineering Design Report for the Radar Processor Simulation for the Joint Surveillance Target Attack Radar System (Joint STARS), Document No. JADS-RPT-002, Code Ident: Q003, date May 1996, Prepared by: Northrop Grumman, 2000 W. NASA Blvd., Melbourne, Florida 32901

(4) ARIES Acceptance Design Review, 30 September 1996, Lockheed-Martin Tactical Defense Systems, Goodyear, Arizona

AUTHOR BIOGRAPHIES

TERRY A. SCHMIDT, Major, US Army is the Team Lead for the End-to-End Test of the Joint Advanced Distributed Simulation Joint Test Force. He received a BS degree in Mechanical Engineering from Kansas State University, and an MS degree in Industrial Engineering and Mathematics from the University of Nebraska.

GARY J. MARCHAND, is the Technical Lead for the End-to-End Test of the Joint Advanced Distributed Simulation Joint Test Force. He received a BS degree from the United States Military Academy and an MS degree in Applied Science from the University of California Davis. He retired from the US Army in 1993 as a Colonel after having been the Deputy Director, TRADOC Analysis Command, 1989-1993.